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OPTIMAL LAND USE FOR WATERSHED MANAGEMENT- A CASE STUDY IN THE FEITSUI WATERSHED

BY

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B.A., ECONOMICS, NATIONAL UNIVERSITY OF CHENGCHI, 2006

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of

Master of Arts
Economics

The University of New Mexico
Albuquerque, New Mexico

December, 2010

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ABSTRACT OF THESIS

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ABSTRACT

Watershed management has always been a crucial issue, especially in developing regions where watershed residents are comprised of low-income farmers. The Feitsui Watershed in Taiwan is one such agricultural watershed. Traditionally, the watershed management policy targets only pollution abatement, therefore constraining agricultural and other economic development. These regulatory measures are likely to hamper the local economy and worsen the living situation for farmers.

In this paper, I argue that good watershed management should also consider the positive externalities from agriculture. I find that the willingness to pay for farmland amenity is above the profit of agricultural output. Ignoring this amenity value could result in an inappropriate watershed resource allocation.

For the best land allocation of the Feitsui Watershed, I argue that the public good nature of land should not be overlooked; all the externalities along with the land development should be identified and carefully considered. This study applies McConnell’s (1989) model, comparing the net marginal return between agriculture and watershed conservation, taking into account both negative and positive agricultural externalities. The empirical results suggest that ignoring positive externality values from agriculture will negatively impact the social welfare of the society. The current zoning policy is not an efficient land allocation. The allotment of agriculture land in the Feitsui Watershed should be increased to seven percent of the total area.

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Chapter 1.

Introduction

Watershed management remains a crucial issue. Watersheds provide multiple environmental services such as biodiversity, foresting, water retention, and air purification (Issac, 1998; Guo et al., 2001; Costanza et al., 2002; Wunder, 2007; Asquith et al., 2008). Growing populations and urbanization have increased the demand for watershed services. Burgeoning urban populations have sprawled to the countryside and watersheds, engaging in all kinds of economic activities. Studies have shown that upstream land development generates various pollutants that accelerate the deterioration of water quality and quantity (Reddy & Behera, 2006; Chou et al., 2007; Hsieh & Yang, 2007; Swinton et al., 2007). Watershed conservation policies seek to prevent further pollution, at the same time restricting local development. A trade-off arises between the externalities and economic development. Furthermore, watershed residents in developing countries are mostly poor farmers (Hope, 2007; Wunder, 2007), so poverty is another issue for the agricultural watershed (Hope, 2007). This makes upstream land planning a complicated problem.

The trade-off between local economic development and watershed conservation policy has always been an important topic (Barbier, 2001). In theory, land as a kind of natural resource can be allocated efficiently by maximizing its competitive use of return. However, different land activities could generate non-use values or externalities that do not have market value. In economic theory, the interaction between supply and demand affects the price. When supply decreases (increases) or demand increases (decreases), the price of the good will go up (down) to reflect people's actual value of the good. However, when it comes to natural resource, property rights are difficult to define. The price mechanism will fail to operate, thus generating an externality. An externality occurs when people engage in certain economic activities but do not have to be responsible for the costs or cannot enjoy the benefits created from the activity. Externalities will therefore result in market failure and require government intervention to adjust the unrecognized value. Because of its public good characteristic, land allocation should be considered not only as a limited resource distribution problem but also in light of the value of externalities.

The Feitsui Watershed located in Taipei County in northern Taiwan currently is the only supply of potable water to twenty percent of the population (250 millions of people in Taipei City and 240 million people in Taipei County) of Taiwan in the Taipei Metropolitan Area (Taipei, 2004). In the Feitsui Watershed, upstream agricultural activities, including fruit and vegetable farming, generate containment runoff and discharge to the water body and are the major source of water pollution (Li & Yeh, 2004; Hsieh & Yang, 2007). It is hard to regulate these agriculture externalities because of their nature as nonpoint source pollution[1] (Li & Yeh, 2004; Chou et al., 2007; Hsieh & Yang, 2007).The most direct way to control nonpoint pollution is by regulating these activities in the watershed. In order to protect water quality of the Feitsui Watershed, the government has demarcated 690 square kilometers of upstream land as the Taipei Water Protection Area in 1984 and applied zoning policy (Chou et al., 2007); as a consequence the local residents have been subject to limitations of land development and strict regulation of all potential pollution sources in the area.

[1] Nonpoint source pollution by its name means pollution from many sources and not from a specific location.

The goal of the current zoning policy is to have 95.5% of the watershed as protection area, 2.6% as public infrastructure, 0.41% as residential area, 0.01% as recreational area, and 0.14% as agricultural area of the total 69,074 hectares (ha) land in the Water Protection area (Wang, 2002).

In this paper, I ask whether this zoning policy in the Feitsui Watershed is the most efficient way to allocate watershed land. I argue that the current measures view agriculture only as a notorious pollution maker but do not consider it as a positive amenity. The positive externalities of agriculture have been noted by many researchers recently value (Beasley et al., 1986; Drake, 1992; Lin, 1998; Li, 2002; Li & Yeh, 2004; Abler, 2005; Chang & Ying, 2005; Lin, 2006; Wiggering et al., 2006; Yu & Lu, 2006). Originally, the primary function of agriculture was only food security, but the multifunctionality of agriculture has been fully recognized since 1990 (Abler, 2005). Based on the definition of multifunctionality of agriculture from the OECD glossary, “agriculture is an economic activity with multiple outputs, both commodity goods and noncommodity goods, and can meet various demands of the community on land use (Wiggering et al., 2006).” According to the literature, positive externalities of farmland, including open space amenities, cultural heritage, groundwater recharge, biodiversity, greenhouse gas sinks, and so forth, could have great economic value (Beasley et al., 1986; Drake, 1992; Lin, 1998; Li, 2002; Li & Yeh, 2004; Abler, 2005; Chang & Ying, 2005; Lin, 2006; Wiggering et al., 2006; Yu & Lu, 2006). Hence, overlooking the positive externalities of agriculture could result in an inefficient policy.

In order to examine the current zoning policy, I formulate a simple land allocation model from McConnell (1989), maximizing the marginal benefits of land return.

Between the two competitive land uses—conservation and agriculture—the model becomes a demand-and-supply system of agricultural land. After empirically estimating the demand and supply for farmland, I find that the current zoning goal for agriculture, 95.5 hectares, is too conservative a number even under a private market approach that takes into account only the negative agricultural externalities. My model indicates that in order to attain private market equilibrium, current agricultural land should decrease from 6,116 hectares to 1,395 hectares. I find that the elasticity of farmland demand and supply are –0.14 and 0.06 respectively. Both of them are inelastic and very close numbers. These results probably arise because the private market model could not reflect the actual marginal value of agricultural land. It explains only part of the cost-benefit decision of the local residents whose major concerns are the agricultural commodity production profit and the pollution cost. I assume that the marginal benefit of agricultural land also includes the values of public goods from its multifunctional nature.

The external benefit of agriculture can be divided into two parts: amenity value and cultural heritage. Farmland provides unique landscape benefit and comfortable space. Studies have shown that more and more urban people seek countryside amenities during weekends, and studies also estimated the willingness to pay for the amenity or recreation value (Drake, 1992; Lin, 1998; Li, 2002; Li & Yeh, 2004; Abler, 2005.; Chang & Ying, 2005; Lin, 2006; Wiggering, 2006; Yu & Lu, 2006; Guo, 2009). With the advantage of the nearby Taipei Metropolitan Area, the Feitsui Watershed becomes a retreat away from the turmoil of the cities. On the other hand, the cultural heritage benefit can be viewed as the preservation of countryside. The study area has produced tea since the Qing Dynasty in 1810 and had been managed by different companies from China, England, and Japan

(Huang & Lin, 1997; Chu, 2005). It preserves traces of the historical tea-making culture of Taiwan. Further, there are several agricultural festivals in the Taipei Water Protection Area held by local governments that have unique characteristics of the study area (Cheng, 2005; Guo, 2009). In this paper, I refer to both of these agricultural externalities as amenity values.

Because of the limitations of time and money, this research adopts a benefit transfer method for estimation of positive agriculture externalities from other studies related to the focus of my study and forms a price range of amenity values. The average annual willingness to pay (WTP) for agriculture amenity is approximately 0.214 New Taiwan Dollars (TWD)[2] (0.007 US dollars) per person per acre with the 95% confidence interval range between -0.00377 and 0.01767 US dollars. The total annual WTP from 24,700 local residents are 172 US dollars per hectare.

I incorporate the estimated positive agriculture externalities as a shifter of my demand equation. I find that the quantity demanded of agricultural land increases to 6,884 hectares. It confirms my assumption that neglecting positive agricultural externalities could result in a biased and inefficient resource allocation. To maximize the social welfare of a watershed, all the nonmarket value externalities should be identified and valued.

To sum up, the current zoning goal in the study area is found very strict: it allows less than one percent of farmland in the watershed. Given the results of this paper, no matter the government identifies the amenity value of agriculture or not, the current zoning goal should be relaxed at least to the current farmland level. If the zoning goal is

[2] In Oct 2010, one USD is approximately equal to 32 TWD (New Taiwan Dollars). Prices in the rest of paper indicated as USD using the above rate.

not adjusted, it could result in great economic loss. In watershed management, agriculture can not only contribute pollution, but also bring prosperity to the local economy with appropriate monitoring. Environmental education, organic farm may be some solutions to balance environmental conservation and economical development. I hope this paper could draw attention to the government in Taiwan, in order to have a better watershed management policy in the Feitsui Watershed.

Chapter 2.

Background

The goal of this chapter is to provide an in-depth survey of the social-economic and environmental aspects of the Taipei Watershed Protection area through the description of my collected data. I find that the existing zoning and regulations policies may directly influence the loss of local population and traditional farming lifestyle. I argue the idea of farmland preservation should be considered as an option of watershed management. Reviewing studies that support the idea of positive externalities from farmland, I find that in the study area, agriculture could have substantial amenity and recreational values due to its multifunctionality. Finally, I review studies of watershed management, their methods and findings.

2.1 Study Site Description

The Feitsui Reservoir is located in Taipei County in northern Taiwan, around 30 kilometers (km) from Taipei City. It was completed in 1987, with a storage volume of 406 million cubic meters (Chou et al., 2007). The reservoir with a hydroelectric power plant was built primarily for domestic water supply. The water usage is estimated at 3.456 million cubic meters daily (Chou et al., 2007). The Feitsui Reservoir was expected to meet the potable water demand for the Taipei metropolitan area until the target year 2030 (Chou et al., 2007).

In 1984, the Taipei Water Protection Area was the first demarcated zone under urban planning law to protect water supply, water quality, and water quantity of the

Feitsui Watershed. The Protection Area, located southeast of the Taipei metropolitan region, has an area of 690 square kilometers- about one third of the Taipei County. The Taipei Water Protection Area covers five different local administrative jurisdictions, which includes five townships: all of Pin-Lin and Wu-Lai; part of Shung-Shi, Shu-Ding, and Xindian (Figure 2.1.1). The area is also under the jurisdiction of the Feitsui Reservoir Administration, which belongs to Taipei City. The mismatch between the water protection area and the local governmental jurisdictions has caused ambiguous authority and policy replication, which decrease the watershed management efficiency and raise confusion.

Figure 2.1.1 The Jurisdictions of Water Protection Area.3

Most pollution in the Feitsui watershed comes from agricultural activities (Hsieh & Yang, 2007). Pesticides and fertilizers are flushed off the watershed surface and carried into the reservoir during storms. Excessive nutrients cause eutrophication and increase drinking water treatment costs, and sediments shorten the lifespan of the

[3] Figure source from Wang (2002) page 4-3.

reservoir. In order to control pollution, currently there are a number of regulations applied to the Taipei Watershed Protection Area as (Table 2.1.1 and Table 2.1.2).

These regulations, including land development confined zone, fertilizer restrictions or strict sewage charge standards aim at only controlling negative externalities from mostly agriculture activities.

Categories		**Description**
Resource Management	Logging	Not allowed
	Sandstone Quarrying	Not allowed
Land Development	Industrial Estate	Not allowed
	Pleasure Ground	Not allowed
	Hospital	Under 50 beds only
	School	Elementary school only
	Hotel	Not allowed
	Golf Course	Not allowed
	Livestock	No allowed
Pollution Control	Fertilizer	With special requirements
	Sewer	Required
	Sewage Discharge	With special requirements
	Water Play Activities	Not allowed

Table 2.1.1 Legislations Addressing Water Quality Protection in the Feitsuei Watershed.[4]

[4] Table source from Wang (2002) page 2-17.

Categories	Area (ha)	Percentage (%)	Land Use Restrictions
Residential Area	279.9	0.4	Construction is permitted only on land with slope under 30%. Factories are prohibited.
Business District	2.2	0	
Protection Area	66091.2	95.7	Except the existing dwellings, all other building prohibited.
Agriculture Area	95.5	0.1	No livestock Limited fertilizer usage.
Forestry Research Area	546.6	1.0	For academic use only
Recreational Area	5.9	0.0	No construction activity.
Catchment Area	139.5	0.2	No construction activity.
Public Infrastructure	1914.1	2.6	
Total	69074.8	100	

Table 2.1.2 The Planned Zones and Restrictions on the Feitsuei Watershed.[5]

Table 2.1.2 above shows the zoning goal for the Feitsuei Watershed. It plans to turn 96.5% of the watershed into conserved land (protection area and forestry research area) with no residents or economic developments. However, to alleviate the abrupt change of lifestyle of the local residents, currently the government agrees to keep the existing land use while keeping the local residents under strict pollution monitoring, but would not allow new land developments (Wang, 2002). By discussing the statistical information later, I still argue the zoning policy (goal) hampers the local economy and has a profound influence on the watershed residents.

Agriculture is the major economic activity in the area, including fruits, vegetables, rice, and tea. Among them, the Feitsui Watershed is most famous for its tea production

[5] Table source from Wang (2002) page 2-18.

because of its weather and geographic advantages[6] (Cheng, 2005). Eighty percent of the population of Pin-Lin and Shung-Shi engage in tea production (Wang, 2002). It was the first place for growing tea and had the largest tea farm area in Taiwan. Tea production can be traced back to the Qing Dynasty around 1810. When the tea plantations in northern Taiwan reached a considerable size, they naturally involved considerable commercial tea activities (Huang & Lin, 1997; Chu, 2005). At first, tea was sold only within Taiwan (Huang & Lin, 1997; Chu, 2005). Around 1820, the tea produced here was exported to mainland China (Huang & Lin, 1997; Chu, 2005). After 1858, western capitalists entered and dominated the Taiwan tea industry (Huang & Lin, 1997; Chu, 2005). In 1866 Dodd & Co., owned by British merchant John Dodd, first purchased a tea farm in the Feitsui Watershed area, and later attracted the interests of other investors (Huang & Lin, 1997; Chu, 2005). European business companies had established export-oriented tea production in the area; Taiwanese tea began to emerge in the world and flourished (Huang & Lin, 1997; Chu, 2005). During the Japanese colonial period, colonial authorities industrialized tea production. After the Japanese left in 1949, the Taiwanese government continued the Japanese management style of mass production, which prohibits private production of tea in small amounts, in order to earn foreign exchange (Huang & Lin, 1997; Chu, 2005). In 1982 the government finally allowed private tea selling and production. From then Taiwanese tea has entered an era of homegrown and retail selling (Huang & Lin, 1997; Chu, 2005).

Figure 2.1.2 illustrates that tea farm acreage in the Feitsui Watershed Area is decreasing. In 1980s, with the opening of private tea farm production, tea farms increased

6 The altitude of the area is from 50 to 250 meters. 84% of the watershed has a gradient 30% or higher, which is good for the growth of tea.

dramatically all over Taiwan; however, in contrast to other regions, the tea farm acreage in the Feitsui Watershed dropped from 2,137 hectares to 1,908 hectares, decreasing about 11%. Its tea yield also dropped from the first to the third among all major tea producing area. Not only tea farms have declined; since 1984, the foundation year of the Taipei Water Protection Area, agricultural land has been steadily decreasing (Figure 2.1.3). From 1980s to today, the Feitsui Watershed has lost about 2,000 hectares of farmland- around one fourth of it.

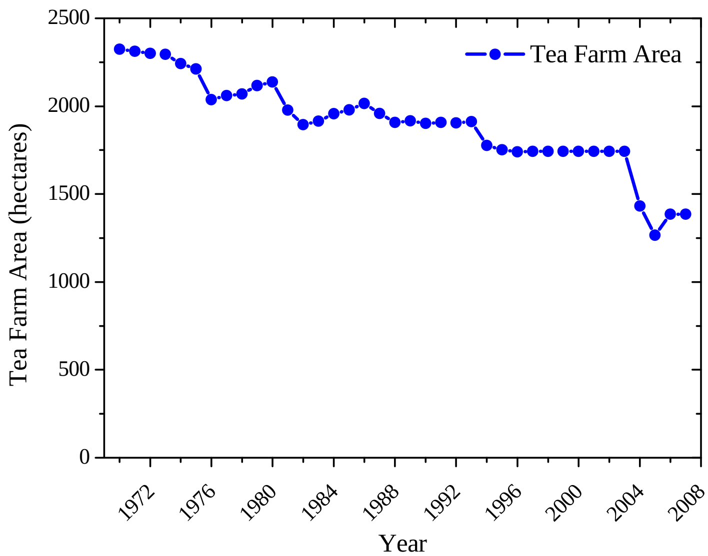

Figure 2.1.2 Change of Tea Farm Area (hectares) in the Feitsui Watershed.

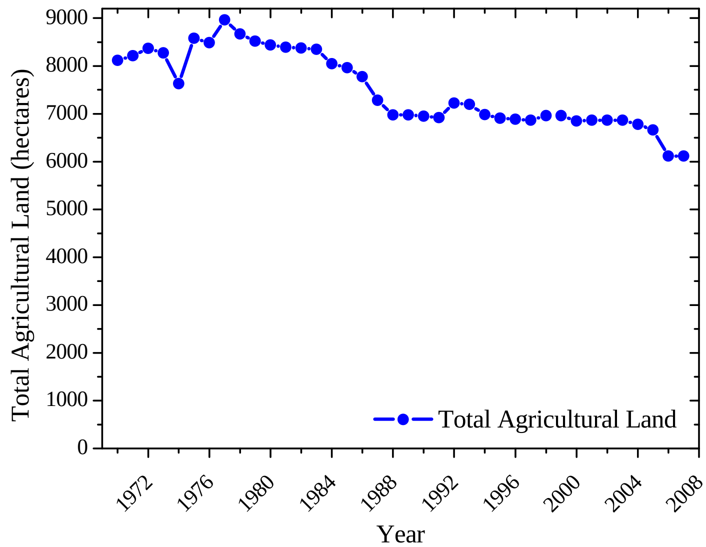

Figure 2.1.3 Total Agricultural Land (hectares) in the Taipei Watershed Protection Area

As shown on the Figure 2.1.4 below[7], the population of the study area decreased after the Water Protection Area was implemented (1984). The later increase in population since 1994 is due to the recreational development of hot spring in Wu-Lai, and the construction of the new residential community buildings in Xin-Dian (Cheng, 2005). Xin-Dian Township, while mostly not located in the Taipei Protection area, has become popular suburban residential area, and stimulated the construction of the two new residential community buildings in the Water Protection Area of Xin-Dian. For the other three agricultural townships, the statistical figures show the possible linkage between population and agricultural land loss, and zoning policy. One effect of zoning on tea production decreases may be that today, the tea production is chiefly on family farms in the study area (Wang, 2002). When the other producing locations replaced labor with

[7] The significant growing population on year 1985 is due to local election for the every first time in Pin-Lin (Taipei County, 2002). This ghost population moved their household register out right after election and have not really lived in Pin-Lin.

machines for mass production, tea production in the Feitsui Watershed became limited by the zoning policy and restrictive fertilizer standard, with comparative disadvantage in both price and quantity. Also, prohibition of land reclamation challenges the tradition of passing down the family tea farm through generations, and could cause massive population loss. Now the population of the study area is mainly consists of elderly and children. Research indicated the loss of labor force can be ascribed to the watershed conservation policies (Han, 2002; Wang, 2002).

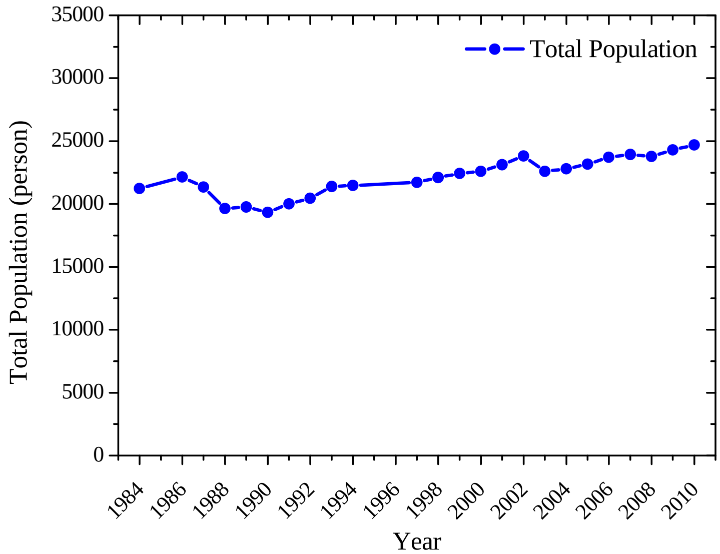

Figure 2.1.4 Total Population Trend in the Taipei Water Protection Area

As mentioned above, the current watershed management policy focused on pollution control (regulations and zoning) has changed the appearance of the Feitsui Watershed. The loss of labor and agricultural land indicates the difficulties of the local economy. When considering watershed management, pollution control alone is not enough; social planning should take into account all the aspects including local economic development. Extensive research has shown that governments worldwide started to recognize the amenity value of agriculture (Barbier & Burgess, 1997; Huang, 2004), estimated by the contingent valuation methods (Drake, 1992; ; Lin, 1998; Li, 2002; Li & Yeh, 2004; Abler, 2005; Chang & Ying, 2005; Lin, 2006; Wiggering et al., 2006; Yu & Lu, 2006; Guo, 2009;). With watershed management, preserving farmland could not only encourage the growth of the local economy, but also maximize the social welfare. In the next section, I review the literature on positive agricultural externalities and watershed management, considering both conservation and local agricultural development.

2.2 Positive Agricultural Externalities

As described previously, the negative externalities of watershed management on agriculture have been well explored. Recently there have been many studies of the positive externalities of farmland (Beasley et al., 1986; Drake, 1992; Lin, 1998; Li, 2002; Li & Yeh, 2004; Abler, 2005; Chang & Ying, 2005; Lin, 2006; Wiggering et al., 2006; Yu & Lu, 2006). They argue that agriculture will also generate positive externalities from use value, such as amenity value, cultural heritage value, the non-use value, bequest value, and the option value, given the fact that the agricultural land is characterized by irreversibility or high cost to recover (Wiggering et. al, 2006).

Rapid population growth and urbanization have caused increasing loss of agricultural land. Farmland has been decreased steadily in Taiwan since 1950; in 1991 the agricultural land amounted to 473,000 hectares, which dropped to 435,000 hectares in 2002 (Huang, 2004). The disappearance of farmland first drew governments' attention because of the food security issue. Governments seek programs to encourage agriculture and support farmers to maintain agricultural production capacity (Lopez et al., 1994). However, as the average income rises, the quality of life and environmental issues become more important. The benefit of open space and green landscape from farmland should not be neglected. The function of agriculture has been expanded from food production to the ecological or cultural perspective.

The concept of multifunctional agriculture has been recognized since 1990 (Randall, 2002; Zander, 2007). Based on the definition of the Organization for Economic Co-operation and Development (OECD), agriculture is an economic activity with multiple outputs, both commodity goods and noncommodity goods[8] (Wiggering et al., 2006). In other words, the concept of multifunctional agriculture is activity-oriented, and combines the products and byproducts of the production process. In the European Union, this concept has been reflected by their agricultural preservation policies (Abler, 2005; Wiggering et al., 2006). They are aware of the special characteristics of rural communities and recognize that agriculture should be distinguished from other commodities, as it is able to reflect the unique historical and cultural lifestyles (Abler, 2005; Wiggering et al., 2006). There have been many studies in the literature to estimate these nonmarket values from agriculture (Beasley et al., 1986; Drake, 1992; Lin, 1998; Li, 2002; Li & Yeh, 2004; Abler, 2005; Chang & Ying, 2005; Lin, 2006; Wiggering, 2006; Yu & Lu, 2006). This shows that the nonmarket benefits make agricultural land a kind of public good, which requires policy intervention to solve the problems of market failure (Hodge, 2001; Díaz-Bonilla & Tin, 2002; Hall et al., 2004; Randall, 2002; Zander, 2007).

[8] OECD Definition Glossary.

The amenity value of the Feitsui Watershed is reflected by the recreational benefit from tourism. As the average income in Taiwan grows, domestic tourism has expanded. Tourism serves as the second source of the local revenue (Wang, 2002). According to the National Statistical Bureau, the non-conservation area of Feitsui Watershed has about 1,860,000 visitors annually. There are many tea farms that combine tea plantation and recreation, providing agro-life experience services and attracting tourists. The Taiwan Pin-Lin Tea Museum was built for preserving the abundant history of tea production in the Feitsui Watershed with monthly visitors around 2,148 in 2010. Further, there are several agricultural festivals in the Taipei Water Protection Area held by local governments, which have become unique characteristics of the study area (Cheng, 2005; Guo, 2009). For example, Pin-Lin and Shu-Ding held the Oolong Tea Festival annually and Shung-Shi has the Chinese Yam festival. Guo (2009) found that the Yam Festival in Shung-Shi could bring annual economic benefit around 78,571 US dollars.

The current zoning goal is to shrink agriculture in the study area to 95.5 hectares. This measure will reduce the above economic benefits from agriculture and have a serious impact on the local economy.

Although a growing literature has addressed the positive agricultural externalities, there is little discussion about their effect on watershed management decisions. The majority of watershed management papers still focus on the pollution abatement. In the next sections, I review the existing literature addressing watershed management issues.

2.3 Watershed Management Literature

The trade-off between local economic development and watershed conservation policy has always been an important topic (Barbier, 2001). A growing body of literature has applied system dynamics models or GIS software to simulate the interaction between pollution, population, and economic development of watersheds, hoping that incorporating explicit detailed watershed information will draw a clearer picture of optimal land use patterns (Guo et al., 2001; Costanza et al., 2002; Kashimibri et al., 2005; Lant et al., 2005; McColl & Aggett, 2006; Amsalu et al., 2007). The above research predicted the timing of changing land use and did sensitivity analysis to test which parameters are the key factors that affect watershed management goals. Some of them predicted or analyzed the existing government watershed management policies. The goal of this kind of research was often environmental quality control since they are minimizing the total costs. Wu & Irwin (2008) created a spatial model to analyze dynamic interactions between economic and environmental amenities in the context of land development and water quality. They found the private developers could exploit land resources rapidly, and that would lead to inefficient land use and degrade ecosystems. To avoid these inefficiencies, the decision makers should internalize the pollution damages and irreversibility costs. Examples are impact fees for development and a riparian buffer around the lake. Costanza et al. (2002) developed a model that served as a water supply multi-sectoral decision support system for water resources management taking economic and socio-environmental factors into consideration. They reviewed the historical changes in land use/land cover and hydrologic data to analyze trends in a watershed's hydrology. McColl & Aggett (2006) created a spatially explicit model to discuss many aspects of the land use planning process including land suitability analyses; forecasting future land use demand; allocating land-use demand to suitable locations; and evaluating the potential impacts of alternative policy choices and assumptions.

Other watershed management studies simply used cost-benefit analysis to examine specific economic aspects and ignored the interdependent relationships between time and different land uses. Although this approach investigated spatially different traits of the land, without a concrete economic theory, I could not decide whether the outcome maximized the social welfare and is the optimal land allocation.

Chang et al. (1995) used the cited empirical estimation of cost ($/acre) and benefit ($/acre) of six different land use types to create six linear equations with six different objectives. Then they examined, under land limitation and pollution abatement constraints, the optimal land distribution by solving the six equations. They concluded that increasing the residential area is feasible if pollution can be controlled properly, but livestock husbandry cannot be allowed under any circumstance within the Tweng-Wen reservoir watershed. However, this model did not enter the endogenous shadow price of different land uses; it merely compared the total cost and total benefits, not considering the interaction between different land uses.

Furthermore, the literature of watershed management analysis above did not consider all the externalities from land development. Watershed management can be viewed as a resource (land) allocation problem. In welfare economics, when there exist no externalities, a free market under perfect competition should achieve Pareto efficiency where no one can increase his/her benefit without decreasing others' utility. This statement implies that maximum social welfare can achieve optimal resource distribution without market failure, or if there is externality, without government failure. Land allocation is different from other resource management because of the following traits: (1) uniqueness of every parcel of land (2) public good; (3) scarcity (4) nonrenewability (Grevers & Van der Veen, 2005). Because of the above characteristics, land management should be performed through the social planner's perspective; otherwise it will cause market failure and fail to attain Pareto efficiency. With this public good characteristic, land allocation policies should take into account not only the problem of limited resource distribution, but also the value of externalities.

McConnell (1989) developed an optimal land allocation model for agricultural, public, and urban spaces- three types of urban land uses. His optimal land use model can be viewed as maximizing social returns of different land uses, net of all negative or positive externalities. To achieve equilibrium, the marginal social returns of three land uses should be equal to each other in terms of land's shadow price. Using the maximization condition above, he then developed a formula for the rates of change in optimal land use with exogenous parameters.

To conclude, I know that the optimal land allocation model can apply neo-classical theory to analyze the demand and supply for land given the information of externalities. Modeling the watershed land management is a matter of which externalities to select. In this paper, I study the Feitsui watershed with an already enforced zoning policy (Table 2.1.1 and Table 2.1.2) to regulate the negative agricultural externalities. I argue that the positive externalities from agricultural land uses such as amenities, bequest, and existence values, should be considered as well. I use the same approach of McConnell (1989) to discuss the optimal demand for agricultural land and examine whether the existing zoning policy provides the optimal rate of change of agricultural land to forest.

Chapter 3.

Theory

In this chapter, I use a simple optimal land use model to find the optimal land use distribution between agriculture and watershed conservation. The model was first derived by McConnell (1989) and was adopted by Barbier & Burgess (1997) and Lopez et al. (1994). McConnell (1989) pointed out that because of the ability of modern advanced technology, land as a capital resource has higher productivity. Although land was used more and more intensively, the marginal productivity of land will not decrease at an increasing rate. This argument rejects the land rent theory David Ricardo first proposed a hundred years ago (McConnell, 1989). For example, within recent decades, despite the population growth and increasing food demand, the agricultural land across United States is decreasing (Barbier & Burgess, 1997). McConnell (1989) suggested that despite the decreasing importance of land as a major capital of agricultural resource, its significance in economic theory remains unaffected. Instead, growing urban population, income, and recreation demand have emphasized the land's importance on amenities, environment, and recreation. He created a simple optimal land allocation model between urban, agricultural, and public uses and used comparative static techniques to analyze the optimal change rate of different land uses.

Barbier & Burgess (1997) and Lopez et al. (1994) followed the McConnell model and reduced the competitive land uses from three to two. Given the two land uses trade-off constraint, the relationship between marginal benefit of different land uses and shadow prices of land uses could be seen as a demand and supply model. Barbier &

Burgess (1997) extended this static demand-supply system to the dynamic level, utilizing a sustainable forest preservation model. Lopez et al. (1994) supported McConnell's opinion about land's increasing importance on amenity return and estimated *a priori* the actual amenity value of agricultural land. He suggested that under the pressure of population growth, there are substantial agricultural land conversions, which have already drawn the attention of governments (social planners). He then applied the estimated amenity value to analyze the optimal agriculture demand and compared the equilibrium quantity demanded with and without considering the positive externalities from agriculture.

The goal of this chapter is to use the McConnell and Lopez models and approaches to develop an optimal land allocation model for the Taipei Watershed Protection Area between two competitive land uses: agriculture and watershed conservation. Assuming that land use for watershed conservation is only for protecting water supply and does not open the area to the public—therefore without recreation or amenity value—I argue that the current zoning policy neglects the importance of the amenity values that agricultural land provides and takes into account only the pollutions it causes. In the next sections, I introduce the theoretical concept for optimal land allocation, incorporate agriculture amenities into the model, and finally develop the econometrics model for empirically estimating agriculture demand and supply in Chapter 4 which follows.

3.1 Maximization Model

The model sees the optimal land allocation question as maximizing the social return of different land uses (Equation 3.1.1). From Lopez et al. (1994), I select the competitive land uses as agriculture and forest (watershed conservation). Utilizing the concept of multifunctional agriculture discussed earlier in Chapter 2, I assume that the agricultural land can produce not only the return of agriculture products but also noncommodities like amenity values, heritage values, and all other nonmarket positive externalities, and so forth.

$$B^a(L_a, t) + B^f\left(L_f, t\right) + \theta \cdot B^s(L_a, t) \qquad \text{(Equation 3.1.1)}$$

a: agriculture

f: forest (conservation)

s: amenity

t: time

L_a: total agricultural land

L_f: total forest (conservation) land

θ: a parameter that provides free choices of considering agriculture amenity return or not.

B^i: the social return function of i type of land use.

The social return functions $\boldsymbol{B}^{\mathbf{a}}$, $\boldsymbol{B}^{\mathbf{f}}$, and $\boldsymbol{B}^{s}$ are determined by the endogenous variable- quantitative land use- and the exogenous variable- time-; both can alter the value of social return. There may be many interpretations of the exogenous variable: it can be that technology changes enhance the agricultural production ability, or population growth increases the social return value by increasing the population demand of agricultural amenity.

The value of social return of land uses is decided by all of the people within the society. It can be measured by the willingness to pay or willingness to accept. The social return function in the model is the net social value, considering all the benefits and costs. For example, $\boldsymbol{B^a}$, the agriculture social return, would be the profits from agriculture production (agriculture production revenue) minus the production costs and all the negative externalities.

Because I assume the social planner already took into account all the pollutions agriculture made. $\boldsymbol{B^f}$, the forest (watershed conservation) social return, would be the benefits from protecting water minus the policy installation fees.[9]

To maximize the social welfare under land use constraint, Equation 3.1.2 can be solved simply by incorporating the Lagrange multiplier (Equation 3.1.3). For a maximization problem, I assume that all the social return functions, $\boldsymbol{B^a}$, $\boldsymbol{B^s}$**,** and $\mathbf{B^f}$**,** are all concave functions which means the first derivatives of the three marginal return are greater than zero, and their second derivatives should be lee than zero. In this model I see quantity land use as a production input; $\boldsymbol{B^a}$, $\boldsymbol{B^s}$ and $\boldsymbol{B^f}$ all follow the neoclassical theory of production. Marginal social returns for all kinds of land use type are increasing at a decreasing rate.

[9] For example, wages for patrolling police officers.

$$Max.\ B^{a}(L_{a},t)+\theta\cdot B^{s}(L_{a},t)+B^{f}\left(L_{f},t\right)$$

$$st.\, L_{a}+L_{f}=\bar{L} \qquad \text{(Equation 3.1.2)}$$

$$\mathcal{L}=B^{a}(L_{a},t)+\theta\cdot B^{s}(L_{a},t)+B^{f}\left(L_{f},t\right)+\lambda(\bar{L}-L_{a}-L_{f}) \qquad \text{(Equation 3.1.3)}$$

With the total land constraint (Equation 3.1.2), this model becomes a resource allocation problem. There is only a limited amount of land to trade-off between agricultural land and watershed conservation (forest). To maximize the social welfare, a social planner wants to distribute the two land use types efficiently. This optimal allocation can be found only by the previous assumption: all marginal benefits of quantity land use increase at a decreasing rate. If the marginal benefits are constant, I can simply conduct a benefit-and-cost analysis and employ all of land to the most profitable land use. However, in my model, the marginal benefit rates vary. For example, when converting the first unit of agricultural land to forest (conservation), the rational decision is to give up the unit of land with the lowest production return; but as more units of agricultural land are converted to forest, I will lose more fertile land for agriculture. Thus the marginal production rate will follow the diminishing rule.

Take derivatives respectively on $\mathrm{L_a}, \mathrm{L_a}$ and λ. Then derive the maximization necessary and sufficient conditions (3.1.4) (3.1.5):

$$\frac{\partial \mathcal{L}}{\partial L_a} = B_1^a(L_a, t) + \theta \cdot B_1^s(L_a, t) = \lambda \qquad \text{(Equation 3.1.4)}$$

$$\frac{\partial \mathcal{L}}{\partial L_f} = B_1^f\left(L_f, t\right) = \lambda \qquad \text{(Equation 3.1.5)}$$

with $B_1^i = \frac{\partial B^i}{\partial L_i}$, $B_{11}^i = \frac{\partial^2 B^i}{\partial {L_i}^2}$, $i = a, f$

where $B_1^a > 0, B_{11}^a < 0$, $B_1^s > 0, B_{11}^s < 0$, and $B_1^f > 0, B_{11}^f < 0$.

These two conditions imply that the marginal return of each land use should equal the shadow value of land. Under perfect competition, the marginal social return of land should be equal to land rent—the shadow value. Otherwise, land will be converted to the highest return use. The shadow value is the real use value of marginal social return of land use per acre. It reflects the opportunity costs of the trade-off under the constraint (Equation 3.1.2). For example, when making the decision of converting an extra unit of agricultural land to forest, I have to compare not only the marginal benefit it will generate but also the opportunity cost of reducing one unit of agricultural land. Equations (3.1.4) and (3.1.5) therefore represent the decision-making process of considering the benefit and (opportunity) cost of each land use type. For the optimal solution, I can see that is (Equation 3.1.4) is the same as (Equation 3.1.5). When the marginal value from adding one unit of agricultural land is equal to adding one unit of forest land, no one would change the current land distribution, thus attaining the equilibrium of land allocation.

Now consider the cases where $\theta = 0$ and $\theta = 1$ respectively. θ is an indicator function (Lopez et al., 1994), which shows whether the external amenity value from agriculture is fully recognized. If $\theta = 0$, Equations (3.1.4) and (3.1.5) can be interpreted as the system demand functions for agriculture and forest (Equation 3.1.6). The quantity land use demanded changes under different land use values (shadow values). Also, because there are only two land use types, given the limited land constraint, I can see one land use demanded as the other land use is supplied.

$$\mathrm{L_a} = \mathrm{D_a}(\lambda; \mathrm{t})$$

$$L_f = D_f(\lambda; t) = \mathrm{S_a}(\lambda, t) \qquad \text{(Equation 3.1.6)}$$

With demand and supply equations (3.1.6), I can solve for the optimal land allocation graphically (Figure 3.1.1).

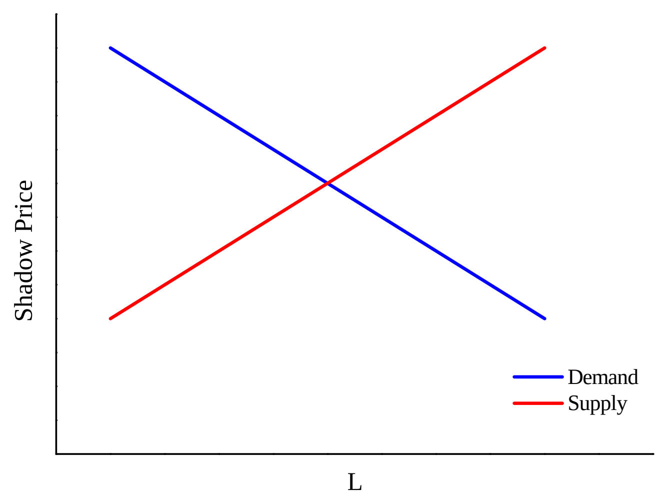

Figure 3.1.1 Optimal Land Allocation

If $\theta = 1$, the agricultural demand function will become (Equation 3.1.7) where $\mathrm{D_a^s}$ stands for the agriculture amenity production function. I could see $\mathrm{D_a^s}$ as the willingness to pay (WTP) for an agriculture amenity.

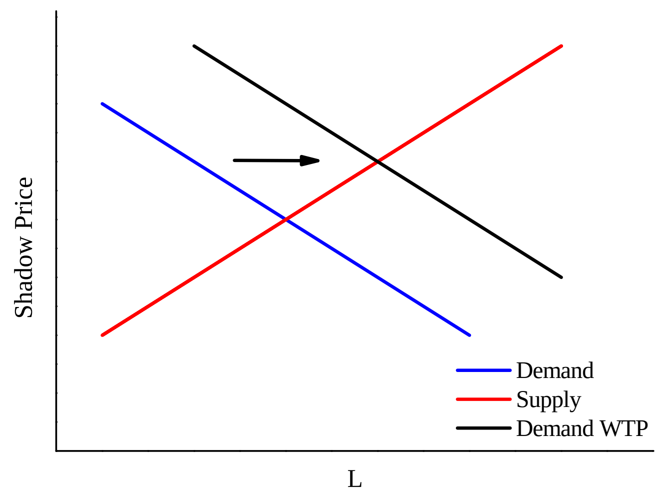

Figure 3.1.2 Optimal Land Allocation with Amenity Value

$$L_a = D_a(\lambda; t) + D_a^s(\lambda; t) \qquad \text{(Equation 3.1.7)}$$

Graphically speaking, if the willingness to pay for amenity value is greater than zero, the demand curve will shift outward and we will have the new equilibrium quantity agricultural land and shadow price (Figure 3.1.2). Hence, overlooking the amenity value would underestimate the optimal quantity of agricultural land and result in an inefficient social outcome. The current zoning policy applied in the study area could decrease the social welfare. However, to verify the specific amount of welfare loss or optimal agricultural land quantitatively requires examining the actual amount of the agriculture amenity value and the elasticity of the demand-and-supply curve.

Because the agriculture amenity is a nonmarket good, it is not possible to observe the value directly. There are several ways to estimate the nonmarket value, including the travel costs method, the contingent valuation method (CVM), and so forth. Conducting the amenity value estimation of the study site will consume substantial time and money and is beyond the perspectives of this paper. Therefore, we used the benefit transfer method to estimate the agriculture amenity value in the study area.

3.2 Benefit Transfer Method

The benefit transfer method borrows the available results from existing literature related to its own research topic, aiming at reducing the time and monetary cost (Boyle & Bergstorm 1992; Brookshire & Neil, 1992; and OECD, 1995). The benefit transfer method is a type of secondary valuation method (OECD, 1995). It refers to the location of literature as study site; and the place where to borrow the results as study site (OECD, 1995).

When conducting a benefit transfer, the characteristics of research site and policy site must be similar. Examples are the characteristics of respondents, income levels, environmental quality and characteristics, socioeconomic variables, and so on. If there are distinct differences between the study site and policy site, it will cause a biased and ineffective transfer (Boyle & Bergstorm, 1992; Brookshire & Neil, 1992). Therefore, careful evaluation before transferring is necessary and the key to have good benefit transfer estimation.

Given the assessment criteria above, this paper will collect and assess literature about nonmarket agriculture products valuation. The literature search covers domestic and international journals. Empirical studies about farmland are mostly from Europe and United States. Comparatively, there are not many studies related to farmland amenities in Taiwan. Evidently, the characteristics of these western countries are very different from Taiwan, both in socio-economic and policy perspectives. On the other hand, when selecting possible studies, I also need to consider the time factor. If a study was published years ago, the whole social environment may change in many aspects; hence it is not appropriate as an effective transfer.

In Taiwan there is no research about tea farm amenity valuation but there are a few studies that focus on positive agricultural environment externalities for paddy fields. Four of these papers were selected as benefit transfer references on the WTP for tea farm in this study. The selected studies will be listed and explained in Chapter 4 which follows.

There are several ways to do benefit transfers: direct benefit transfer, benefit function transfer, and meta benefit analysis (Boyle & Bergstorm, 1992; Brookshire & Neil, 1992). In this paper, I collect only four studies as benefit transfer references. There is insufficient information to conduct benefit function transfer or meta benefit analysis. I apply the direct benefit transfer to this study.

Direct benefit transfer assumes that the characteristics of the policy site and the study site are very similar (Jeng et al, 2005) and directly transfers the estimated average benefits from the study site to the policy site. This method is mostly applied on the recreation benefit studies (Boyle & Bergstorm, 1992; and Jeng et al., 2005). According to the collected studies, I could have a value range of positive agriculture externalities. However, within these collected studies, there must be different characteristics that I have to adjust before deriving the value range, such as deflating the price index or the accord measurement, and so on. Extra information will be needed to form a consistent and unbiased benefit transfer valuation range.

3.3 Econometric Model

In the previous sections, following the first-order conditions of maximizing social welfare, I have systematic equations of supply and demand for agricultural land (Equation 3.1.6). The equilibrium agricultural land quantity and price could be obtained by solving the two equations. However, the exact function form of the demand and supply equations remains unknown. The equations could be estimated empirically through an econometrics method. In this section, I will derive an econometrics model for supply and demand and discuss the appropriate econometrics method to estimate my empirical model.

As mentioned in the earlier section, in Equation (3.1.6), $\mathbf{L_a}, \boldsymbol{L_f}$ are the quantity demanded of agricultural and quantity supplied of agricultural land respectively, and λ is the shadow price of agricultural land. In the competitive market, the shadow price should be equal to the market price (McConnell, 1989). Now, I have both demand and supply equations explained by price, quantity, and some exogenous variables. Equation (3.1.6) can be denoted as following econometrics equation (3.3.1):

$$L_d = \alpha_0 + \alpha_1 P + \alpha_{2i} X_i + \epsilon_d$$

$$L_s = \beta_0 + \beta_1 P + \beta_{2h} G_h + \epsilon_s \qquad \text{(Equation 3.3.1)}$$

$i = 1, 2, 3, \ldots, n$.

$h = 1, 2, 3, \ldots, m$.

L_d: quantity demanded of agricultural land.

L_s: quantity supplied of agricultural land.

P: shadow price of agricultural land.

X_i: ith exogenous variables of demand function.

G_h: hth exogenous variables of supply function.

ϵ_d: the error term of demand function.

ϵ_s: the error term of supply function.

Following studies that estimated farmland demand and supply (Barbier & Burgess, 1997; Doos, 2002; Erb, 2004; Lopez et al., 1994; McConnell, 1989; Yu & Lu, 2006), I list my exogenous factors for demand and supply in Table 3.3.1.

Variable Name (Symbol)	**Explanation of the variable**	**Reference**
TPop	Watershed population	Barbier & Burgess, 1997; Doos, 2002; Lopez et al., 1994; McConnell, 1989; Yu & Lu, 2006.
Consumption	Agricultural consumption (kg)	Erb, 2004.
Production	Agriculture production (kg) per acreage (hectare)	Erb, 2004; McConnell, 1980.
APrice	Price of agricultural product	Barbier & Burgess, 1997.
FPop	Farmer's population	Yu & Lu, 2006.
GDP	National income level	Barbier & Burgess, 1997; Lopez et al., 1994; McConnell, 1989.

Table 3.3.1 Explanations and References of Exogenous Variables

Now I could present my system equations (3.3.1) explicitly as following equation (3.3.2).

$$L_d = \alpha_0 + \alpha_1 P + +\alpha_2\ FPop\ +\ \alpha_3\ TPop\ +\ \alpha_4\ Production\ +\ \alpha_5\ consumption +\ \alpha_6 ln\ APrice\ + \epsilon_d$$

$$L_s = \beta_0 + \beta_1 P + +\beta_2\ FPop\ +\ \beta_3\ TPop\ + \beta_4\ \ gdp\ + \epsilon_s \qquad \text{(Equation 3.3.2)}$$

$$L_d = L_s = L^*$$

$$P = P^* \qquad \text{(Equation 3.3.3)}$$

$$cov(L^*, \epsilon_d) \neq 0\ ;\ cov(P^*, \epsilon_s) \neq 0 \qquad \text{(Equation 3.3.4)}$$

Normally, studies that estimated single demand or supply equations would use the simple correlation analysis by running an ordinary least squares analysis on time series data (Southwick & Butler, 1985). In this paper, on the other hand, the equilibrium price and quantity are found by solving the demand and supply equations simultaneously (Equation 3.3.3). There are feedback effects between the two equations. It is called a system of simultaneous equations: the price and quantities demanded and supplied, known as endogenous variables, are decided collectively and simultaneously. Ordinary least squares analysis assumes that explanatory variables on the right-hand side will affect dependent variables in one way. However, in my model, price can not only explain the variation of the quantity of agricultural land demanded in the demand equation but also again affect the quantity demanded by the error term, which is explained by the supply equation (Stock & Watson, 2002). Therefore, applying an OLS estimator in my model will violate the presumption of the interdependence between explanatory variables and the error terms. In order to resolve the endogenous relationship among price and quantity supplied, my research adopts a two-stage least squares (2SLS) method.

As mentioned earlier, the time series data of equilibrium price and quantity collected for empirically estimating demand and supply were decided by each other. Besides, at every time period the demand and supply will be affected by some exogenous variables and shift the curves (Stock & Watson, 2002; Baum et al., 2003). The relationship between the time series data was neither the demand nor the supply function. As depicted in the following Figure 3.3.1, the correlation between equilibrium points A, B, and C is meaningless (Stock & Watson, 2002). Therefore, simply using the information to run OLS will cause inconsistent estimators that are not close to the true value even with large samples (Baum et al., 2003) and could not capture the shift of demand and supply caused by the exogenous variables (Angrist & Krueger, 2001). P. G. Wright (1928) found if we could find some instrumental variables that exogenously explain the variation of price but are not correlated with the error term, the inconsistent problem of OLS will be solved (Stock & Watson, 2002). Graphically speaking (Figure 3.3.2), I could first fix the demand or supply function and allow only the other equation to shift (Stock & Watson, 2002). In order to conduct this approach, I have to find the reduced form of both the demand and supply equations.

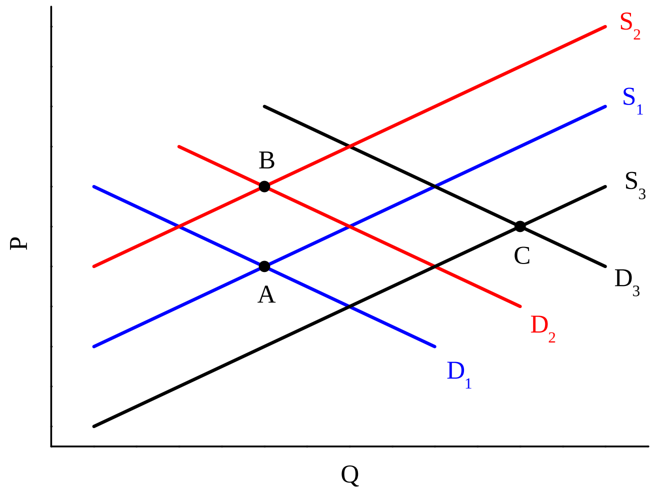

Figure 3.3.1 Equilibrium Points at Different Time Periods[10]

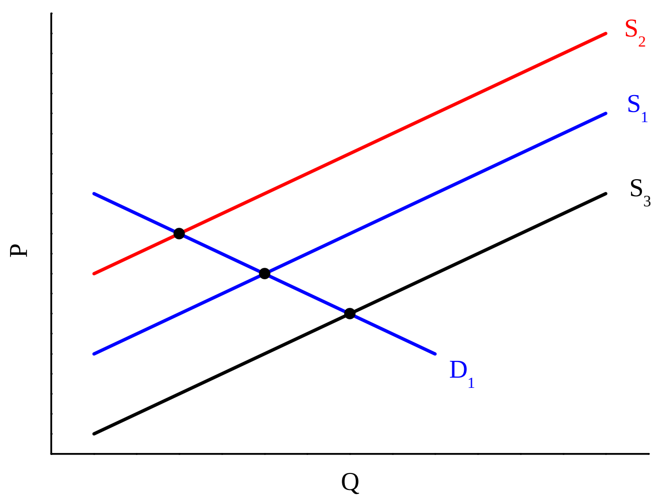

Figure 3.3.2 Equilibrium Points Estimation with Fixed Demand[11]

[10] Figure source from Stock & Watson (2002), page 336.

[11] Figure source from Stock & Watson (2002), page 336.

Equation (3.3.3) stated that $\mathbf{L_a}$ must be equal to $\mathbf{L_f}$ at equilibrium. I could then set the two expressions in (3.3.2) equal to each other and get the reduced form for price-hat (Equation 3.3.5).

$$\hat{P} = \pi_0 + \pi_1 FPop + \pi_2\ TPop\ +\ \pi_3\ Production\ +\ \pi_4\, consumption\ +$$
$$\pi_5\ APrice\ +\ \pi_6\, gdp +\ \epsilon_3 \qquad \text{(Equation 3.3.5)}$$

Use all exogenous variables as instrumental variables to estimate $\widehat{\mathrm{P}}$. Then insert $\widehat{\mathrm{P}}$ into the demand and supply equation (3.3.2). I assume the exogenous variables are uncorrelated with the error terms ϵ_{d}.and ϵ_{s} .

Chapter 4.

Data

From the previous chapter, I establish the econometric model of optimal agricultural land allocation. The variables that compose the model of optimal farmland are listed as follows (Equation 4.1). Detailed descriptions of each variable selected for the demand and supply equations provide in this chapter. This chapter presents the data needed to conduct empirical analysis. First, I show sources of information used in this study, discuss all the necessary variables estimating my demand and supply equations, and finally list studies collected about agriculture externalities in Taiwan, creating a price range for benefit transfer.

$$\mathrm{L_a} = \mathrm{D_a}(Shadow; FPop, TPop, APrice, Production, consumption)$$

$$L_f = S^a(Shadow; FPop, Tpop, GDP) \qquad \text{(Equation 4.1)}$$

In this study, I use tea farms as my agricultural land, because tea production is the major agricultural activity within my study area. The next most popular plantation is vegetables. For example, the following table (4.1) shows the total plantation of the five townships in 2005. 58% of agricultural land was used as tea farms, 25% as vegetables, and 17% as orchard.

Area	Tea (ha)	Rice (ha)	Vegetable (ha)	Orchard (ha)
Xindian	68.5	5.5	204.0	180.4
Shu-Ding	518.8	0	143.8	35.6
Ping-Lin	675.4	0	17.7	25.1
Shung-Shi,	3.7	7.5	73.4	60.4
Wu-Lai	0	68.5	132.7	48.1

Table 4.1 Total Agriculture Plantation of the Five Townships in 2005

Since the agricultural land demand and supply are denoted by the demand and supply of tea farm, tea price (Barbier & Burgess, 1997), tea consumption (Erb, 2004), and tea production per hectare (McConnell, 1989; Erb, 2004) were chosen to explain my demand function. Among the five townships, Wu-Lai is special with its hot spring resources and has not produced tea since 1983. Hence I drop Wu-Lai for my analysis; I include only the information of Pin-Lin, Shung-Shi, Shu-Ding, and Xindian.

4.1 Data Description

I collect the annual data of the Taipei Watershed Protection Area from 1980 to 2003, including agricultural land quantity, current agricultural land return, tea price, total tea consumption in Taiwan, tea production per hectare, total number of farmers, total population of the protection area, and national GDP in Taiwan. Most of the data were derived from the Taipei County Year Book; Tea Price and Tea Consumption in Taiwan are from the Taiwan Tea Union; and GDP is from the National Statistical Bureau. The information in early periods was ignored because, before 1984 the Taipei Watershed Protection Area had not been created yet and the demographic data of the specific jurisdiction cannot be found. Also because the Taipei Watershed Protection Area is only a jurisdiction under strict water pollution control, not an administrative division- it does not have statistical organization and therefore lacks statistical information. I collect information from the five townships Xindian, Shung-Shi, Shu-Ding, Pin-Lin, and Wu-Lai, which cover the study area. However, Shung-Shi, Shu-Ding, and Xindian, only partially belong to the Taipei Watershed Protection Area, so the township statistical data do not exactly match my study area. I ignore this fact and applied my collected data to the whole watershed area.

McConnell (1989) pointed out that with the advanced technology, higher production efficiency will decrease the demand for agricultural land because the same amount of farmland activity could yield more production. This suggests a negative sign of yield per hectare. In this study, tea production per hectare is the total tea production (kg) divided by tea farm acreage (hectares). The average tea production efficiency is 1.7 kg per hectare with standard deviation 0.98. The average production efficiency among the four townships is similar.

The information on tea consumption and tea prices obtained from the Taiwan Tea Union is nationwide. Tea consumption is the total domestic tea consumption, including all kinds of tea. The average total tea consumption in Taiwan from 1980 to 2003 is about 28.9 million kilograms: 40% is of imported tea and 60% of domestically produced tea. 90% of domestically produced tea is consumed in the country. Japan is the largest importer of tea for Taiwan. To meet the domestic demand of tea, Taiwan has to import tea from Southeast Asia countries, such as Vietnam and China. Figure 4.1.1 below shows that the tea consumption in Taiwan is steadily increasing. Erb (2004) found that agriculture demand strongly depends on consumption level. Hence, I expect a positive sign on this variable, assuming more tea consumption will increase the demand for tea farms. The price between different kinds of tea and different quality levels of tea could vary drastically. My study area is famous for the origin of the Wen-Shan Bao-Zhong tea, a kind of Oolong tea. Because the time-series of Wen-Shan Bao-Zhong tea price is not available[12], I utilize Oolong tea price data in Taiwan. Also, due to lack of information, although the tea quality may change from the four townships, I assume they are priced the same. To capture the inflation rate, I further deflate the nominal tea price to CPI. The average real price of Oolong tea is 3.7 US dollars per kilogram; the standard deviation is 1.79. The tea price had a growing trend from 1984 to 1994, remained unchanged for 6 to 7 years, and dropped a little recently (Figure 4.1.2). I assume that the high tea price is an incentive to produce more tea, and thus increases the demand for tea farms.

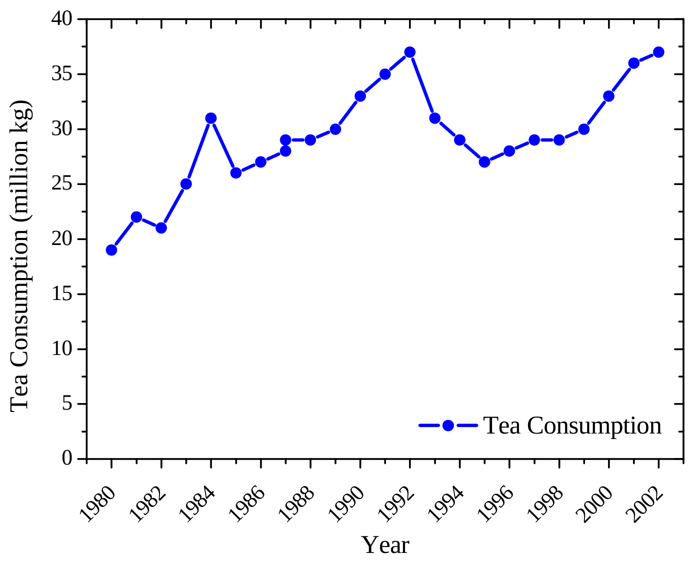

Figure 4.1.1 Average Tea Consumption in Taiwan

[12] The prices of the Wen-Shan Bao-Zhong tea are made by individual sellers (planters). Price range could vary and there is no complete data at hand.

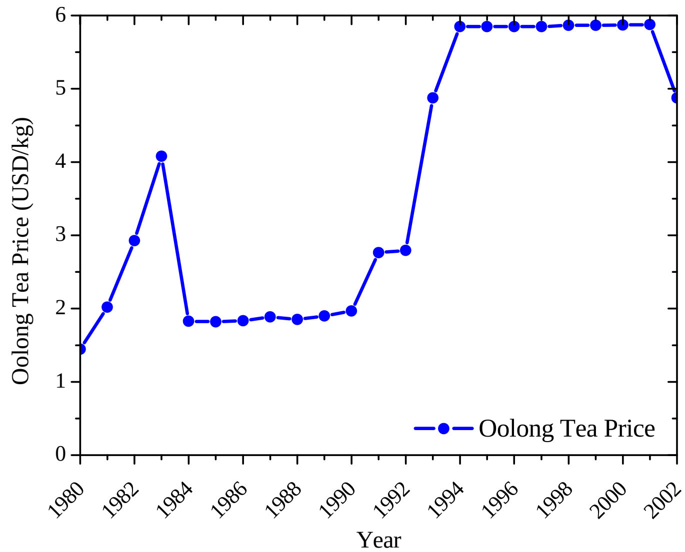

Figure 4.1.2 Average Oolong Tea Price in Taiwan (US dollars/kg)

Many studies found population as a major factor for agricultural land demand and supply (McConnell, 1989; Lopez et al., 1994; Barbier & Burgess, 1997; Doos, 2002; Yu & Lu, 2006). Lopez et al. (1994) found that population was significantly correlated with demand positively and negatively with supply. McConnell (1989) pointed out that a growing population will increase agricultural land demand because of its amenity value. In this study, I include two variables, total population of the Taipei watershed area and total number of farmers within the five townships, to distinguish the land demand from producers and average residents. The total population of the Taipei watershed area was obtained from the Taipei County Year Book. I identify all the villages located in the study area and add all the populations of those villages to obtain an actual population of the study site. The average population is 4,598 in the four townships. As Figure 4.1.3[13] below indicates, except for Xin-Dian, the population of the other three decreased over time. The population sizes of the four townships are very different and the standard deviation is large.

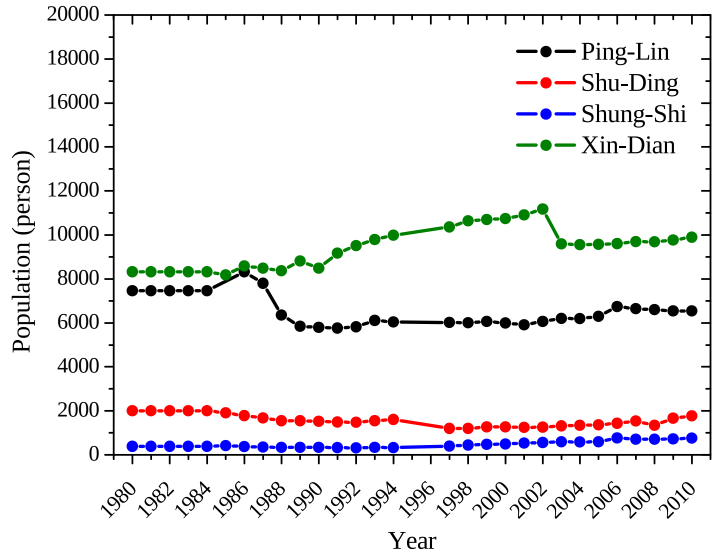

Figure 4.1.3 Population Trend in the Taipei Water Protection Area

The farmer's population is also from the Taipei County Year Book. I use aggregate farmers' numbers of the four townships because there is no information of each village and the actual tea farmers. The average farmer population is 3,937 in the four townships. Figure 4.1.4 shows that the farmer population has a comparatively smaller deviation among townships but greater variation through time.

[13]In 1985, the first local election brought a considerable number of citizens to move their 'household registers' here in order to vote, but they did not physically live in Pin-Lin. I drop this unreal population number in year 1985 in my analysis.

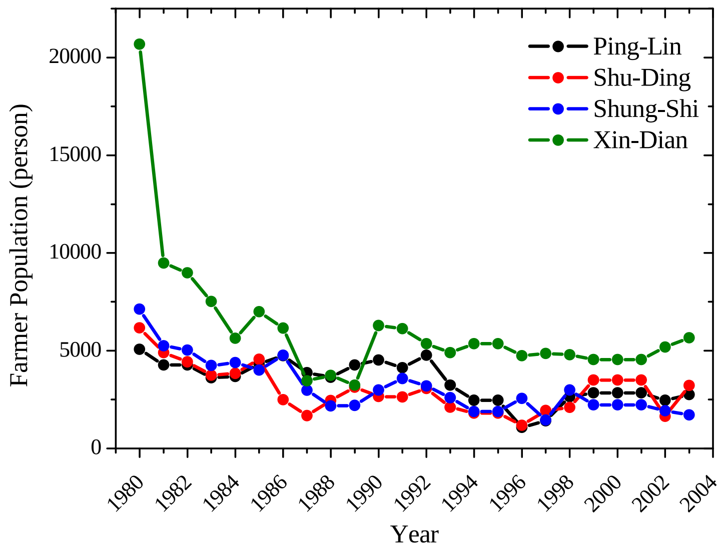

Figure 4.1.4 Farmer Population in the Four Townships

In this study, average income is expected to explain the tea farm supply. I assume that higher average income will increase recreational demand (Barbier & Burgess, 1997; Lopez et al., 1994; McConnell, 1989) and have a negative sign in the supply function (Lopez et al., 1994) because the conservation forest is not open to public. The national income was represented by the real GDP data from the National Statistical Bureau. The average of real GDP is 19,351 US dollars. Studies had shown that with increasing national income in Taiwan, the recreational demand on both domestic and foreign travel has been expanding (Hsiao, 2002; Chang & Ying, 2005; and Shih, 2009).

From McConnel's land distribution model, when the marginal return of each land use is equal to the shadow value of land, there will be the most efficient land allocation. The shadow value of land is the exact use value of the land. The use value of land should be equal to the market price under perfect competition. Social maximization could be attained by solving demand and supply equation given shadow value and land quantity.

In reality, I have only information on the existing quantity of land and the government published current price of land. The information of agricultural land market price is unavailable. The Land Administration Bureau provides only regional current land prices on a village basis. In this study, I use the current land price as my agricultural land price proxy. The average price is 121.5 US dollars per square meter (Figure 4.1.5). The standard deviation is 17 US dollars with a minimum price of 0.49 US dollars per square foot and a maximum price of 5,357 US dollars per square foot.

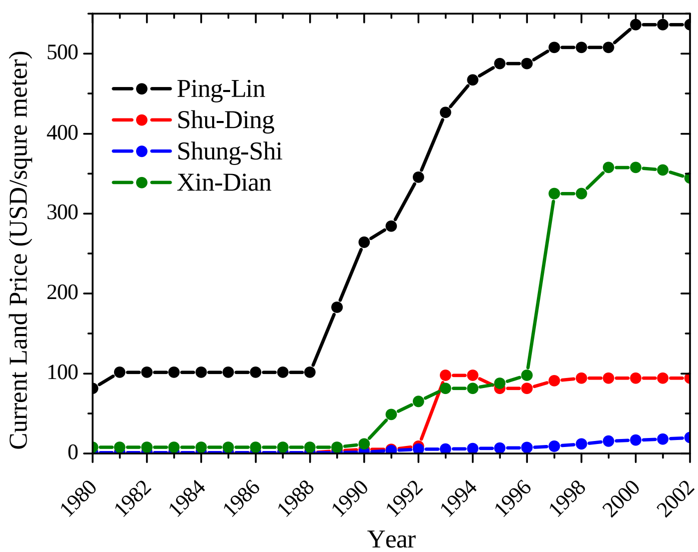

Figure 4.1.5 Current Land Price (USD/square meter) in the Four Townships

I assume that a tea farm is a normal good. Following the economic theory, I expect a negative relationship between quantity and price in the demand equation, and positive sign on supply equation. As the value of agricultural land decreases, consumers will demand more land for amenities; and farmers will demand more land to develop. Likewise, when the return of conservation decreases, the government or social planner will release more conservation forest for other uses.

The tea farm quantity is a straightforward concept. However, the tea farm information of each township is unavailable for the earlier years. Instead, I simply gather annual agricultural land[14] quantity records from the Taipei County Year Book. From Figure 4.1.6 below, I found that each area has a different trend. Except for Xin-Dian, the total agricultural land remains unchanged for a long time. It is probably because the zoning policy limits the growth of developing agricultural land. Only a small part of Xin-Dian is located in the study area. Since my data includes all the agricultural land within this township, the decreasing trend of agricultural land may be interpreted with the increasing urbanization in this area.

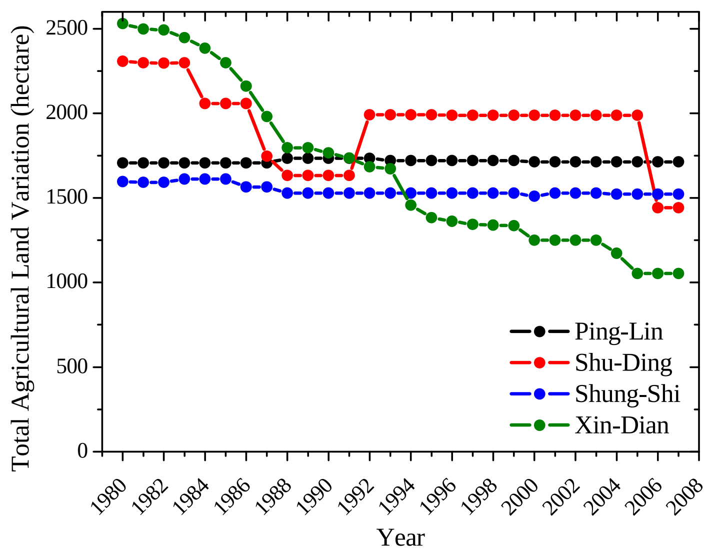

Figure 4.1.6 Total Agricultural Land Variation in the Four Townships.

Finally, I summarize the symbol, expected sign, and basic descriptive statistics of the variables in the following tables (4.1.2 and 4.1.3).

[14] The agricultural land in general, not specifically tea farms.

Functions	**Variables**	**Expected Sign**	**Source**
	Current land return (**Shadow**)	$\frac{\partial \mathrm{D_a}}{\partial Shadow} < 0$ $\frac{\partial \mathrm{S_a}}{\partial Shadow} > 0$	Land Administration Bureau
	Tea farms (**Land**)		Taipei County Year Book (1970-2007)
Demand ($\mathbf{D_a}$)	**Tpop**	$\frac{\partial \mathrm{D_a}}{\partial TPop} > 0$	Taipei County Year Book (1970-2007)
	Fpop	$\frac{\partial \mathrm{D_a}}{\partial FPop} > 0$	Taipei County Year Book (1970-2007)
	Consumption	$\frac{\partial \mathrm{D_a}}{\partial consumption} > 0$	Taiwan Tea Industry Statistics
	Production	$\frac{\partial \mathrm{D_a}}{\partial production} < 0$	Taipei County Year Book (1970-2007)
	APrice	$\frac{\partial \mathrm{D_a}}{\partial APrice} > 0$	Taiwan Tea Industry Statistics
Supply ($\mathbf{S_a}$)	**Tpop**	$\frac{\partial \mathrm{S_a}}{\partial TPop} < 0$	Taipei County Year Book (1970-2007)
	Fpop	$\frac{\partial \mathrm{S_a}}{\partial FPop} < 0$	Taipei County Year Book (1970-2007)
	GDP	$\frac{\partial \mathrm{S_a}}{\partial\, gdp} < 0$	National Statistics Bureau

Table 4.1.1 Variables Sources, Symbols, and Expected Signs

Variables	Min	Max	Mean	Std. Dev.
Land(ha)	1,249	25,31	1,760	290
Shadow(TWD/m^2)	15	16,500	3742	5222
Pop(person)	1,069	20,683	3937	2381
Production(kg/ha)	0.45	3.20	1.70	0.99
Consumption(kg)	19,018,836	36,502,194	28,915,139	4,440,635
GDP(TWD)	233,112	891,445	596,453	248,619
TPop(people)	310	19,107	4,598	4,005
Tea Price(TWD)	44	181	116	55

Table 4.1.2 Statistical Description of the Variables

4.2 Benefit Transfer Information

To empirically analyze the optimal land allocation, taking into account the positive externalities from agriculture, I need information about the willingness to pay for amenity values for tea farms. From Chapter 3, I find that to obtain such information requires research applying nonmarket valuation methods consisting of questionnaires or face-to-face survey. Confined by the time and money limitation, this study will use the benefit transfer method to form a price range of the willingness to pay for agriculture amenities.

After reviewing available studies, I find no studies researching on my study area or specifically estimating nonmarket tea farm value. However, there are some studies about studying rice farm or general agriculture nonmarket values in Taiwan. I select four of these studies most similar to my study topic and describe the detail as following.

Huang (1991) noticed that with growing population, more and more agricultural land has been changed to commercial uses. However, the agricultural land has irreversible characteristics. Once changed to other uses, it is hard to restore its original style and feature. Therefore, he conducted a national questionnaire survey in Taiwan, asking the willingness to pay for food security, existence, and bequest value on paddy field preservation. Questionnaire surveys were collected from Taipei County, Taoyuan County, Hsinchu County, Taichung County, Changhua County, Yunlin County, Chiayi County, Tainan County, Kaohsiung City, and Pingtung County. The sample population included the populace and 10 environmental scholars. He received 288 questionnaire surveys. Analyzing the results of questionnaires, he found that the average annual existence and bequest value of each person are 22 US dollars and 34 US dollars respectively; the food security value under national food-sufficient security levels (Currently, 86%) of 60%, 30%, and 0% are 15 US dollars, 26 US dollars, and 31 US dollars respectively. He later analyzed existence values and bequest values statistically, using Seemingly Unrelated Regression (SUR). He found that household income and education level are the most important factors affecting existence value and bequest value. Also, food securities, amenity functions of rice farms, and land irreversibility characteristics have significant relationships for existence value but not for bequest value. This study did not report the response rate or the standard deviations of its results; however, because the study widely cited and was used on government evaluation, I still include it as my benefit transfer value reference.

Lin (1998) used an open-ended questionnaire, asking the willingness to pay for external benefits from agriculture, including use value, existence value, bequest value, and option value in Taiwan. The research covered both rural and urban areas of Taiwan. 205 questionnaires were sent and 172 valid replies were received: 59 from the northern part of Taiwan, 60 from the middle of Taiwan and 53 from the southern part of Taiwan. Consistent with Huang's (1991) survey, he found that household income, education level, and recreation demand are highly correlated with individual's WTP. The aggregate annual willingness to pay for external benefits from agriculture is 344 US dollars per person with 95% confidence interval the value is between 282 and 406 US dollars, and the total benefit is 7.2 billion US dollars; annual use value is 204 US dollars per person with 95% confidence interval the value is between 128 and 280 US dollars, and the total benefit is 4.3 billion US dollars; annual existence value is 54 US dollars with 95% confidence interval the value is between 30 and 78 US dollars, and the total benefit is 1.1 billion US dollars; annual bequest value is 43 US dollars with 95% confidence interval the value is between 40 and 46 US dollars, and the total benefit is 963.6 million US dollars; and annual option value 44 US dollars with 95% confidence interval the value is between 39 and 49 US dollars, and the total benefit is 921.4 million US dollars. Comparing with the other three references, this study has smaller sample and may have less ability to represent the population.

Although the above two studies were focused on rice farms and general agricultural land, not tea farms, the motivation and concept behind the surveys are similar to this study. I argue that the willingness to pay for Taipei Watershed Protection Area includes not only the amenity value but also the existence, bequest, and option value. Although both studies are comparatively old, they were both sound. Also, national surveys were representative over my policy site (Taipei Watershed Protection Area) because I focus not only on the willingness to pay of regional residents but all population in Taiwan given that all of them could enjoy the amenity values from preserved farmland.

Therefore, I use the annual existence and bequest value from Huang (1991) and the estimated result of Lin (1998) as my benefit transfer references.

Li (2002) asked the willingness to pay for preserving rural lifestyle, including ecological, amenity, and cultural aspects, in Taichung and Changhua. The research designed the questionnaire with the Double-Bounded Dichotomous Choice Elicitation Method. He used a stratified sampling method, selecting 500 adults above 20 years old from the data base of the social science department in Academia Simca. First he offered a random price to the individual to see if he would accept the offer. If accepted, he raised the price until the individual declined the offer. He found that to preserve 60 thousand hectares of farmland, people would accept a monthly payment of 18.7 US dollars per person. In the 95% confidence interval, the value is between 10.2 US dollars and 27.2 US dollars. The total annual payment will be 354.9 million US dollars. In this study, the question design was concrete and specific. Also, the statistics was well provided. Thus it could be a reliable source as my value reference.

Lin (2006) conducted a CVM analysis on Wu-Fong Township in Taichung. He subcategorized all 20 villages in Wu-Fong to 3 categories evaluated by their production function, ecological function, and lifestyle function. He sent 310 questionnaires to those three types of village separately, with an 88% reply rate. According to his analysis, people in Wu-Fong are willing to pay 37 US dollars per person annually for preserving the current rural lifestyle with 95% confidence interval the value is between 35.4 and 39.2. The aggregate annual benefit is 1,455 US dollars per hectare; 36 US dollars to conserve the current ecological function from agriculture with 95% confidence interval the value is between 31.8 and 39.2. The aggregate annual benefit 1,231 US dollars per hectare. Lin (2006) is the latest research of my four benefit transfer references. It also provides well-designed questionnaire and high reply rate.

The above two studies were focused on the WTP for rural style in Taichung and Changhua. In my policy site, I also focus on the regional countryside agriculture amenity. Taichung and Changhua have the largest tea production in Taiwan (Taiwan tea). Wu-Fong is also famous with its tea production. In Lin (2006), the study site is quite similar to my policy site. Also, the face-to-face interview method is representative and valuable in Li (2002). Thus, I choose these papers as my benefit transfer references.

Here we summarize the WTP value from the four above studies. Values are adjusted to be annual per hectare basis.

	Estimated Value Name	Annual Aggregate WTP (US dollars /ha)	Annual WTP per person (US dollars /ha)
Huang (1991)	Existence value of rice farm.	32,714	0.0015
Lin (1998)	Use value, including amenity value, of agricultural land.	30,890	0.0004
Li (2002)	WTP for preserving current rural lifestyle, including amenity value.	9,177	0.0035
Lin (2006)	WTP for preserving current rural lifestyle, including amenity value.	1,454	0.0224

Table 4.2.1 Summary of the Four Benefit Transfer References.

In the above Table 4.2.1, I obtain an individual annual WTP per hectare from 0.0004 to 0.0224. The average WTP is 0.007 with 10% variation and the standard deviation is 0.0104. In the 95% confidence interval, the lower bound is -0.00377 and upper bound is 0.01767. The result of Lin (2006) is comparatively high. Because the studied areas in Li (2002) and Lin (2006) are comparatively small, their WTP per hectare value are higher than the studies of Huang (1991) and Lin (1998). One possible explanation of this is because people do not only value the benefit from agriculture by its size.

Chapter 5.

Results

In this chapter, I use panel data to empirically estimate the demand and supply of the farmland in the Feitsui Watershed. I apply a fixed-effect model for a two-stage least squares estimator. First, through some primer statistical tests, I check for the validity of the model and approach. Second, I present and discuss the regression results from my model; then I compare the equilibrium output to the current zoning policy.

5.1 Primer Test

From economic theory, the quantities demanded and quantities supplied are decided collectively by the price variable. Price can explain the variation of quantity agricultural land demanded in demand equation but also again affects its error term, which is explained by the supply equation (Stock & Watson, 2002). I use the two-stage least square (2SLS) estimator to avoid the endogeneity issue and solve for the demand-supply systematic equations. The 2SLS estimator first uses all exogenous variables as instrumental variables (IV) to predict my endogenous variable, price. Then, I run regression on the demand and supply equation with the IV-estimated estimator price-hat. Before conducting 2SLS method, I have to check for the existence of endogeneity and more importantly the validity of my instrumental variables.

The Durbin-Wu-Hausman (DWH) test could check for the existence of endogeneity (Stock & Watson, 2002). Econometrics result shows that Wu-Hausman F-statistic is 9.9 with a p-value of 0.002. Therefore, I reject the null hypothesis that price is an exogenous variable, which means using an ordinary least square estimator will have inconsistent results. This confirms that my empirical model follows the economic theory and is in favor of the 2SLS estimator.

2SLS estimator uses instrumental (exogenous) variables to explain the variation of the price variable to avoid the endogenous issue. It is important that our instrumental variables are uncorrelated with the error term of the demand and supply equation. This can be checked by the over-identifying restriction tests (Stock & Watson, 2002). First, I find both equations are over-identified by checking whether the number of total variables of the whole system equations minus the number of total variables in one equation is greater than or equal to the number of total endogenous variables of the whole system minus one (Stock & Watson, 2002). Then, the Sargan statistics for demand and supply are 0 and 6.080 respectively, with *p*-values 0 and 0.01 respectively. It shows that my instrumental variables are independent of the error terms. Further, the quality of the instrumental variables depends on how strong they are correlated with the endogenous variables, as tested by the weak identification test (Stock & Watson, 2002). Econometrics result reports that the Cragg-Donald Wald *F* statistics for demand and supply are 24.456 and 1.415. Sotck & Yogo (2005) presented the critical *F*-values under different numbers of instruments. I find that both of my demand and supply equations pass the weak instrument exam.

Panel data in this paper include both cross-sectional (the four townships) and time series information (years 1980–2003). Generally, time series data can explain the dynamic of variable itself (intra-individual), and cross-sectional data can provide parameters that explain the difference between observations (inter-individual)

(Wooldridge, 2002; Yaffee, 2005). Panel data combine the benefit of the above two data types and could decrease the possibility of avoiding an unobserved omitted variable (Greene, 2003; Brick et. al., 2009).

There are two kinds of panel regression models: the fixed effect model and the random effect model (Wooldridge, 2002; Greene, 2003). A Hausman test could help us to decide which model is more appropriate (Wooldridge, 2002; Greene, 2003). According to the econometrics results[15], both of my demand and supply equations favor the fixed-effect model. A fixed-effect model could capture the unobserved characteristics of the four townships. In Chapter 4, through data set development I find that although the four townships share some similar environmental characteristics, the socio-economic status and geographic traits could vary among them. The Hausman test result is consistent with my expectation.

5.2 Regression Results

Although OLS regression will lead to inconsistent estimators, I still incorporate it as a comparison to my 2SLS regression model (Table 5.1.2) in order to achieve robust regression results. Also, I use different function forms and different explanatory variables combination to search a best fit econometric model. I estimate demand and supply on both the linear model and log-linear model by taking the natural log on both sides. From Table 5.2.1 below, although the linear model has similar coefficient results and significant level with the log model, the root-mean-square estimator shows the linear model has only limited explanatory ability of the dependent variable. Applying the log

[15] In this study, I use STATA 10.0 to conduct econometric analysis.

model has several advantages: for example, it could prevent negative estimators and it could easily give us the elasticity. Therefore, I use the log model for the rest of analysis.

Form	**Log**	**Log**		**Linear**	**Linear**
Equation	**Demand**	**Supply**		**Demand**	**Supply**
Variables			**Variables**		
ln(shadow)	–0.13***	0.15*	**Shadow**	–0.00	0.15*
	(–4.49)	(2.30)		(–1.33)	(2.30)
ln(tpop)	–0.28**	–0.35**	**Tpop**	–19.15***	–0.35**
	(–2.58)	(–3.16)		(–4.05)	(–3.61)
ln(Aprice)	0.18*		**Aprice**	865.6***	
	(2.09)			(6.94)	
ln(production)	–0.004*		**Production**	51,155***	
	(–0.09)			(4.59)	
ln(gdp)		–0.60**	**Gdp**		–0.60**
		(–3.16)			(–3.16)
_cons	10.84***	17.20***	**_cons**	-7,526	17.20***
	(11.29)	(6.83)		(-0.19)	(6.83)
N	95	95		95	95
RMSE	0.15	0.14		361	242
Chi square	223,293	228,194		749	4,941
***p* value of chi statistics**	<.0001	<.0001		<.0001	<.0001
corr(u_i, X_b)	–0.95	–0.87		–0.82	–0.92

Table 5.2.1 Regression Results on Linear and Log-Linear Models

After examining the combination of explanatory variables, because the local population is mainly comprised of farmers, the change of farmers **FPOP** has a strong relationship with the change of local population **TPOP**. National income **GDP** also shares the same trend with tea consumption **COMSUMPTION**. Since literature had shown that the change of national income could significantly explain the change of the tea consumption in Taiwan (Chou, 2005). The Pearson's correlation coefficient table confirms the high coefficient numbers between them. I further examine the multicollinearity with Variance Inflation Factor (VIF), but find no multicollinearity with all VIFs less than 10. However, to avoid similar explanatory variables, I drop **FPOP** and **CONSUMPTION,** in light of their lower significance in my results compared with the other variables. Table 5.2.2 below presents both OLS and 2SLS results on the original variables setting and the scenario dropping **FPOP** and **CONSUMPTION**. The OLS and 2SLS have inconsistent coefficient signs and different significant levels. Only the best combination scenario using has the expected sign except local population **TPOP**, which I discuss in the next section. The matrix of correlations among the regression coefficients, corr(u_i, X_b), is slightly smaller on the best combination scenario. What this means is that in spite of dropping two variables, the best combination scenario has lower correlation with the unobserved characteristics for the four townships (Tabeling, 2007).

Method	**OLS (all vars included)**		**OLS (Best combination)**		**2SLS (all vars included)**		**2SLS (Best combination)**	
	Demand	**Supply**	**Demand**	**Supply**	**Demand**	**Supply**	**Demand**	**Supply**
Variables	**lland**	**lland**	**lland**	**lland**	**lland**	**lland**	**lland**	**lland**
ln(shadow)	–0.03**	-0.02*	–0.04**	0.01	–0.09***	-0.02	–0.13***	0.06
	(–3.37)	(-2.15)	(–3.69)	(0.68)	(–4.16)	(-0.62)	(–4.49)	(0.78)
ln(tpop)	–0.05**	0.06**	0.05**	–0.23***	–0.28**	–0.27***	-0.28**	–0.31**
	(–2.94)	(3.1)	(3.16)	(–3.57)	(–3.19)	(–3.45)	(-2.58)	(–2.96)
ln(fpop)	-0.04	–0.06			0.02	–0.00		
	(-1.13)	(–1.53)			(0.39)	(–0.11)		
ln(gdp)		–0.13**		–0.21***		–0.12		–0.33**
		(–2.67)		(–3.49)		(–1.34)		(–1.62)
ln(aprice)	0.12		0.01		0.13*		0.18*	
	(2.19)		(1.82)		(2.09)		(2.09)	
ln(production)	0.12***		0.10**		0.01		–0.00	
	(3)		(–2.63)		(0.26)		(–0.09)	
ln(consumption)	–0.29**			9.13***	-0.16			
	(–2.92)			(14.01)	(-1.65)			
_cons	12.28***	9.56***	7.16***	12.01***	13.18***	11.52***	10.84***	13.24***
	(5.47)	(12.86)	(29.74)	(12.74)	(6.55)	(8.72)	(11.29)	(6.73)
N	95	95	95	90	95	95	95	95
R^2	0.42	0.41	0.34	0.41	0.23	0.41	0.09	0.04
F **value**	10.3	15.2	11.2	20.5	8.71	14.45	8.42	12.03
p **value of** ***F*–Statistics**	<.0001	<.0001	<.0001	<.0001	.	.	.	.
RMSE	0.11	0.12	0.11	0.11	0.12	0.11	0.15	0.14
Chi square					337,333	449,060	223,293	228,194
p **value of chi**					0	0	0	0
corr(*u_i*, *X*b)	-0.96	–0.95	–0.95	–0.95	–0.95	–0.95	–0.95	–0.93
t **statistics in parentheses *=** $p<0.05$**; **** $p<0.01$**; ***** $p<0.001$								

Table 5.2.2 OLS and 2SLS Regression Results on Different Combinations of the Explanatory Variables.

Equation 5.2.1 below is my final estimated demand model with RMSE value 0.15. The matrix of correlations among the regression coefficients, corr(*u_i*, *X*b), is –0.95, which means the unobserved characteristics of the four townships on my demand model will decrease the expected farmland demand (Tabelling, 2007); also, the number is fairly large; in the future more explanatory variables could be included to capture the different characteristics of the four townships. In the demand model, all independent variables are significant at least with 95% confident interval. The price elasticity in demand is negative 0.13, which means a 10% rise in current price of farmland would decrease the farmland demand about 1.3%. This gives us an inelastic price demand. If the government would like to interfere in land allocation in the study area, price may serve as a tool with limited ability. Other than the watershed population variable, all the other independent variables have an expected sign. Tea production efficiency, as McConnell predicted, has a negative relationship with the land demand. Therefore, the growing demand of farmland reflects not only the productivity of food, but also the farmland's amenity (recreational) value. Tea price with the highest elasticity with farmland demand and comparatively lower significance explains the traditional economic assumption on land theory.

$$\ln Land = 10.84 - 0.13 \cdot \ln Shadow - 0.28 \cdot \ln TPop - 0.004 \cdot \ln Production + 0.18 \cdot \ln APrice$$

(11.29***) (–4.49***) (–2.58**) (–0.09**) (2.09*)

RMSE = 0.15 $\mathrm{corr}(u\_i, X_b) = -0.95$ (Equation 5.2.1)

$$\ln Land = 13.24 + 0.06 \cdot \ln Shadow - 0.31 \cdot \ln TPop - 0.33 \cdot \ln gdp$$

(6.73***) (0.78) (–2.96**) (–1.62**)

RMSE = 0.14 $\mathrm{corr}(u\_i, X_b) = -0.93$ (Equation 5.2.2)

Equation 5.2.2 above is my final estimated supply model with RMSE value 0.14. The matrix of correlations among the regression coefficients, corr(u_i, X_b), is –0.93, which means again that the unobserved characteristics of the four townships will decrease the expected farmland supply (Tabelling, 2007). All independent variables of the supply model are significant at least with 95% confidence interval. The price elasticity in supply is 0.06, which means a 10% rise in current price of farmland would decrease about 0.6% in the farmland supply or conservation demand. The inelastic price supply seems reasonable in my model. Since the area of farmland conservation is decided by the governments, people will be less sensitive to the price change in farmland. The negative relationship between GDP and farmland supply confirms my assumption that growing national income will lead to more recreational spending. Therefore, the farmland amenity value will be respected.

One of the reasons that the watershed population has a negative sign relative to the farmland demand may be the zoning policy. Agriculture has been subject to many limitations in the study area, so residents lost their interest and ability to engage in agriculture development. As the result, increasing local residents will not increase the farmland demand. In my assumption, I expect a positive sign because I argue that local residents will view amenity value from farmland greater than the actual agriculture productivity. At first, one may conclude that local residents do not respect the amenity value of the farmland, but when I look at the elasticity of local population in the supply side, I find that it has the expected negative sign. This means when population grows, demand for conservation forest with no public access permission will decrease, and people will be in flavor of farmland. Also the elasticity of local residents on supply is greater than on the demand side. The negative sign of the local residents on demand may also arise, because the positive externality value from agriculture- with its non-commodity nature- does not bring actual revenue to the local residents, compare to agriculture production. Therefore, the magnitude of traditional farmland return is bigger than its amenity value.

5.3 Equilibrium of Farmland Demand and Supply

Using (Equation 5.2.1) and (Equation 5.2.2), I can estimate the optimal quantity demanded and price of farmland demand and supply, where *A* and *B* can be estimated by the constant term and all other explanatory variables multiplied by their average mean.

$$L_d = A + \hat{\beta} P_d$$

$$L_d = B + \hat{\mu} P_d \qquad \text{Equation (5.3.1)}$$

The private market equilibrium price is 386,694 US dollars per hectare and the optimal farmland area is 1,359 hectares. I find that even with the private market condition, which takes into account only the negative agriculture externalities, the zoning goal of 95.5 hectares of farmland is way below the optimal level. On the other hand, the optimal price of farmland at 386,694 US dollars per hectare (calculated based on Equation 5.3.1) is much greater than the average current farmland price 121,880 US dollars per hectare (calculated on page 46). According to the definition from the Land Administration Bureau, the purpose of the current farmland price used in this study is for the government imposed land tax. Based on social and economic conditions, reference to land acquisition compensation and actual land transactions in the market over the past year, the government designated the current land price range for tax reference. The current land price is a number reduced by a certain percentage of the actual market price. Therefore, it is reasonable to assume that the price information in this study has been underestimated. I argue that this private market result is not efficient because it overlooks the importance of the positive externalities from agriculture. To have a maximum social welfare outcome, I could incorporate the estimated WTP from Chapter 4 into my research.

Through benefit transfer, my estimated annual WTP per person ranges from 0.0004 to 0.0224 US dollars per hectare with average number 0.007 (Table 4.2.1). The willingness to pay per hectare could be regarded as a shifter of farmland demand. Adding a constant WTP number at every price level will generate a new demand curve parallel to my private market demand curve (Figure 3.1.2). When applying minimum WTP estimation, the optimal farmland quantity is 2,779 hectares; with maximum WTP estimation, the suggested farmland area raises to 10,614 hectares. Figure 5.3.1 shows the results of different policy scenarios.

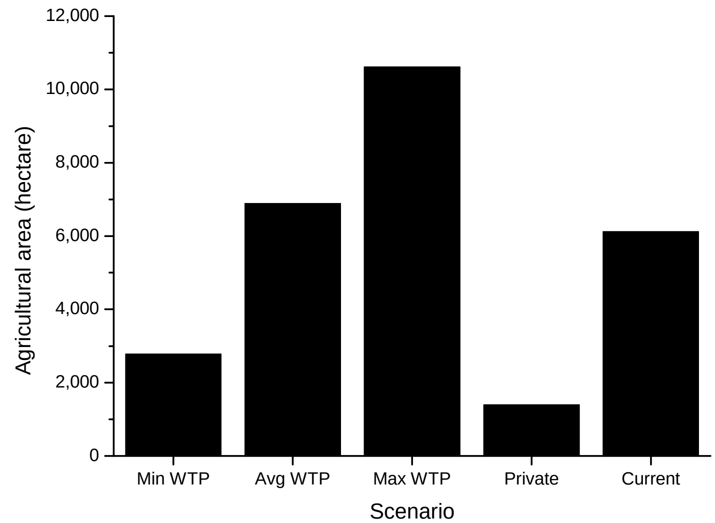

Figure 5.3.1 The Estimations of Optimal Agricultural Land

Incorporating the average annual WTP per person estimation per hectare, 0.007 US dollars with the 95% confidence interval range between -0.00377 and 0.01767.US dollars, I find that quantity demanded of agricultural land has increased to 6,884 hectares. This reflects that positive agriculture value could have tremendous influence on farmland allocation. Ignoring this aspect will decrease social welfare. Currently, the average agricultural land area in the Feitsui Watershed is 6,116 hectares. My model suggests that it still has room to welcome farmland development considering the amenity (recreational) it could bring to the society. The government should reconsider the current zoning goal, since it seems to be very severe and disregards the local economics of the Feitsui Watershed. After all, the local economy of the study area is relatively poor. In the future, site-specific nonmarket valuation research could help the decision making of the government. I hope that authorities could identify the importance of the positive externalities from farmland and the recreational revenue that the local economy could enjoy.

Chapter 6.

Conclusion

Farmland preservation in the Taipei Watershed Area is a means of protecting agricultural production and the cultural and recreational aspects of agricultural amenity. In this study, I find that amenity, existence, and bequest values from farmland could generate much higher economic value then the actual agricultural output return. Therefore, to achieve a more efficient watershed management, the social planner should have a more comprehensive understanding of these nonmarket externalities from agriculture. Positive agricultural externalities cannot be ignored for watershed management. I find that considering and developing amenity values from farmland could be a solution for balancing the conflicts between local economy and watershed conservation.

Using the observed annual current farmland price and farmland area in the Feitsui Watershed, I construct equations for farmland supply and demand and solve them with the Two Stage Least Square Method, which can capture the simultaneous actions deciding the equilibrium price and quantity. I find that the demand for farmland in the Feitsui Watershed is affected by local population, tea price, and tea production efficiency; the supply is affected by the local population and national income. The equilibrium price is 386,693 US dollars and the equilibrium farmland size is 1,359 hectares. This result suggests that the current farmland price is much underestimated. The marginal benefit from farmland is higher than the current farmland price that the government published. A comparison of the equilibrium farmland with the current agriculture area in 2010 shows that the current farmland size of 6,116 hectares should be decreased to 1,359 hectares; The zoning target farmland allocation of 95.5 hectares is inefficient and will lose the production value from agriculture.

The model above is based on the empirical information from years 1980 to 2003. The data were collected from a period under zoning policy; the analysis compares the cost benefit only from agriculture production and its negative externalities. I argue that this kind of evaluation does not consider the positive externalities from agriculture, underestimates the marginal benefit of agriculture, and represents only the private market equilibrium. The amenity value from agriculture has been recognized in recent years. Studies have shown that the increasing national income in Taiwan increases the demand for recreation, open space, and culture heritage value from farmland. Because these positive services are nonmarket services, they need nonmarket valuation to estimate their actual price. Owing to the money and time constraint of this study, I review studies of positive agricultures and conducted benefit transfer analysis to form a price range of the willingness to pay (WTP) for agriculture amenity. I find that in Feitsui Watershed, in year 2010 the average annual WTP is 171 US dollars per hectare. This finding confirms my assumption that ignoring the agriculture amenity value could result in inefficient watershed management and diminish social welfare.

I then add the estimated WTP to the previous model and find a significant increase on the equilibrium farmland. Quantity demanded and supplied of agricultural land has risen to 6,884 hectares. This suggests that about 0.1% of the watershed could be employed for agricultural use. Currently, the average agricultural land area in the Feitsui Watershed is 6,116 hectares. My model suggests that it still has room to welcome farmland development considering the amenity (recreational) it could bring to the society. I hope this result could draw the government's attention to reconsidering the zoning policy of the Feitsui watershed.

In the future, more detailed willingness to pay research of the study area could yield more realistic and valid statistics for policy making. Also, one should note that the limitations of my collected data. If more information could be found before the year 1980, one could have a comparison between the farmland demand before and after the zoning policy put in place on 1984. The availability of actual market farmland prices could improve the reliability of my model. Further, one should note that because my matrix of correlations among the regression coefficients, corr(u_i, X_b), is fairly high, more variables could be tested and added to have a more concrete explanation for the different characteristics of the four townships.

With the growing national income, rising recreational demand could help boost countryside economy. I argue that the traditional farmland production revenue is not sufficient for living in the Feitsui Watershed, given the regulatory measures for protecting water quality. Massive plantation or other reduced cost plans for agricultural production are not practical in the study area and would result in the loss of competitive advantage of price. Governments should reconsider the importance of the amenity benefit from farmland. In the Feitsui Watershed, a region of Taiwan having a relative poor economy, well-developed recreational agricultural resources may favor the local community, which is continuously suffering from loss of population. With good environmental education, recreational economic development can also assist the control of watershed pollution. Further, organic agriculture may be another way to balance between tea farm preserving and environmental conservation. Organic tea plantation generates less pollution and has more awareness on the food safety and environmental conservation. With less pollution per hectare of farmland, the agricultural land can increase more and boost the local economy. Organic tea farm could also attract environmental conscious tourists and customers. It may be another policy option for watershed management.

To conclude, the current zoning goal is very strict under all policy scenarios. To practice the zoning goal, the farmland has to decrease 64 times of the current size. This measure will lead to drastic change of the watershed landscape and severe damage on the local economy. I argue that the zoning policy used overkill now: farmland may be the main source of pollution, but agriculture is also main source of local revenue. My model suggests that government should consider the importance of amenity value from agriculture and keep the size of current farmland. Also, the government could also decrease pollution by encouraging organic tea plantation or green production. I hope the government in Taiwan could find the best watershed management addressing the trade-off between environmental conservation and local development.

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